AD-A139 446 PHONON TRANSPORT THROUGH SOLID INTERFACES(U) INDIANA UNIV-PURDUE UNIV AT INDIANAPOLIS W E BRON 31 DEC 83 N00014-78-C-0249 1/1

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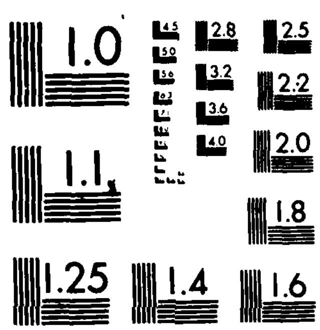

MICROCOPY RESOLUTION TEST CHART
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Final Report

to the Naval Research

ONR Contract Number: N00014-78-C-0249

Period of Contract: March 1, 1978 to December 31, 1983.

Title of Contract: Phonon Transport through Solid Interfaces

Name of Institution: Indiana University

Principle Investigator: Prof. W.E. Bron

I. Research Program

During the lifetime of the contract the following research areas were undertaken.

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A. Emission of Phonons into a Dispersive Medium

The acoustic mismatch model of the injection of phonon distributions into a solid considered phonon transport within the solid to be ballistic. We had, however, detected that this was not the case for a dispersive solid; that is, for one containing elastic scattering sites[1]. To explain these results, Schaich[2] proposed that the origin of this effect lies in a frequency dependent elastic backscattering of phonons resulting in a reverse flow of primarily high frequency phonons from the solid to the phonon source.

An experiement[3,4] was performed to test the proposed mechanism. For this purpose we used a further condition noted by Schaich;[2] namely, that a time dependent variation in the "temperature" of the metal heater film would also be present. The experimental technique made it possible to measure quantitatively the time dependence of the temperature of the heater film during, and after, electrical excitation. The experiment was conducted on samples containing significant concentrations of foreign, or isotopic impurities and on a sample

containing only very small concentrations of isotopic impurities.

The experimental results showed conclusively that the predicted time-dependent temperature is observed, and that it scales with the concentration of foreign and isotopic impurity ions. It was found to be essentially absent in samples containing only small amounts of isotopic impurities. The magnitude of the effect is shown to be in good overall agreement with Schaich's model.

These observations indicate that in cases in which good thermal transport across solid-sold interfaces is required, as is the case in integrated circuitry, that only substrates free of isotropic and foreign impurities should be used.

B. Lifetimes of High-frequency Phonons

Earlier work in the laboratory[1] had indicated that the frequency dependence of the lifetimes of longitudinal acoustic (LA) phonons did not obey the theoretically predicted frequency (ω) dependence of ω^{-5}. It has since been realized that a part of this anomaly stems from the presence of elastic scatterers (imperfections or isotopic impurities) in whose presence the high frequency phonons reach a quasiequilibrium amoung themselves and that their "lifetime" represents the slow cooling of this quasiequilibrium, and not the intrinsic lifetime of the phonons

themselves. The full ramifications of this rather complicated nonequilibrium phonon dynamics is still under investigation . A prelimimary report was recently presented at the International Conference on Phonon Scattering[6].

C. Phonon Lifetimes in Piezoelectrically Coherently Excited Quartz.

A particulary strong anomalous phonon lifetime had been observed by others for very high (≈3.5THZ) phonons in piezoelectrically coherently excited quartz. Since coherent phonon dynamics, per se, is of important scientific interests and also of some interest technologically (as acoustic amplifiers) we mounted an experiment to investigate the anomaly.

After an exhaustive study at Indiana University and at the Max Plauck Institut fuer Festkoerperforschung - Stuttgart it was shown that the previous observations by Grill[7] were in error and that piezoeclective surface excitation at these frequencies were unlikely to occur at conventionally optically polished quarts surfaces[8].

An extension of these results to the production of suitable surfaces through the techniques of modern surface science is currently being proposed to NSF and ONR. A preliminary theorectical investigation on this topic was

presented at the Internal Conference on Phonon Physics[9].

References

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2. W.L. Schaich, J. Phys. C11, 4341 (1978).

3. W.E. Bron, J.L. Patel and W.L. Schaich, Phys. Rev. B20, 5303 (1979).

4. W.E. Bron, Phonon Scattering in Condensed Matter, Ed. H. Maris (Plenum: NY) 1980. pg. 349.

5. W.E. Bron, Phys. Rev. B21, 2627 (1980).

6. T.E. Wilson, W.E. Bron, F. M. Lurie and W.L. Schaich, to be published in the Proceedings of the Internal Conference on Phonon Scattering, Stuttgart, 1983.

7. W. Grill, 1977 Ulhasonics Symposium, IEEE Cat. no 77 CH1264-ISU.

8. W.E. Bron, M. Rossinelli, Y.J. Bai and F. Keilmam, Phys. Rev. B27, 1370 (1983).

9. J. Throwe and W.E. Bron, J. Physique 42, C6-849 (1981).

In addition to the citations above, the following papers were published on work either wholy or partically supported by contract funds.

1. W.E. Bron, Rep. Prog. Phys. 43, 301 (1980).

2. W.E. Bron, Defects in Insulatin Crystals, Ed. U.M. Tuchkevich and K.K. Shvartz, (Springer: Berlin) 1981, pg. 560.

3. W.E. Bron, Phonon Generation, Transport and Detection through Electronic States in Solids. To be published n "Nonequilibrium Phonons in Luminescent Crystals" Ed. W. Eisenmenger and A.A. Kaplyanskii.

II Personnel Supported

1. Professor W.E. Bron, Principle Investigator
2. Professor F.M. Lurie, Faculty Associate
3. Dr. M. Rossinelli, Postdoctoral Associate
4. Dr. J. L. Patel, Postdoctoral Associate
5. T. Wilson, Graduate Student, Ph.D. February, 1984.
6. J. Throwe, Graduate Studnt, Ph.D. expected 1985.

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